Geological Survey of Canada
Commission géologique du Canada

PAPER 85-11

WINDSOR GROUP SALT IN THE CUMBERLAND SUBBASIN OF NOVA SCOTIA

R.D. Howie

1986

Canada

86-04232/

Geological Survey of Canada
Paper 85-11

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Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Canada K1A 0S9

and from

Geological Survey of Canada offices:

601 Booth Street
Ottawa, Canada K1A 0E8

3303-33rd Street N.W.,
Calgary, Alberta T2L 2A7

100 West Pender Street
Vancouver, British Columbia V6B 1R8
(mainly B.C. and Yukon)

A deposit copy of this publication is also available
for reference in public libraries across Canada

Cat. No. M44-85/11E Canada: $5.00
ISBN 0-660-12087-9 Other countries: $6.00

Price subject to change without notice

Critical Readers

J.S. Bell
P.S. Giles
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Original manuscript submitted - 1984 -06
Final version approved for publication - 1985 - 01

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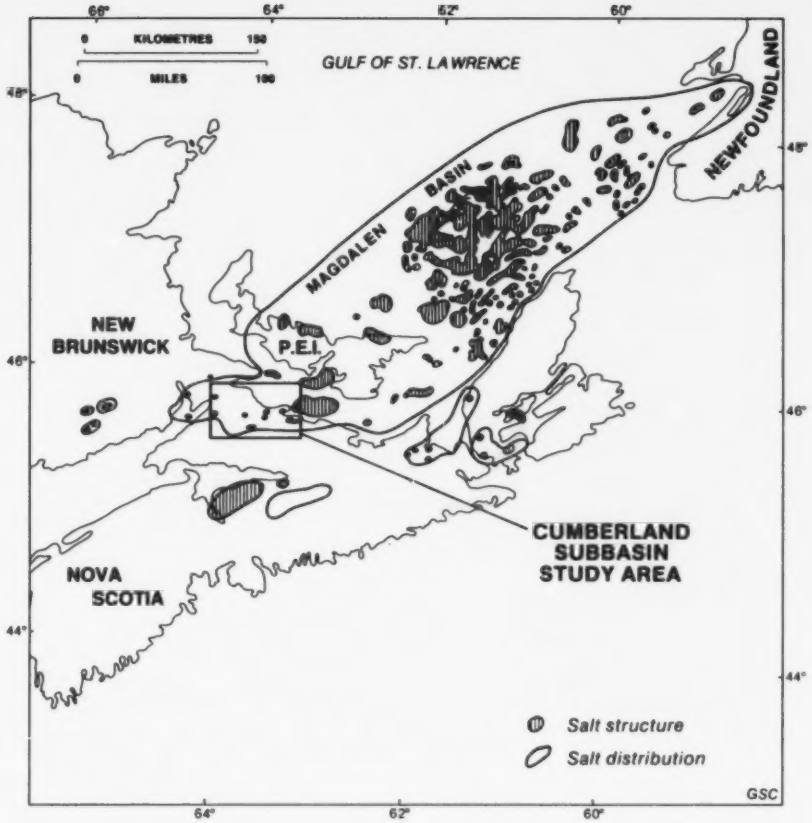

Figure 1. Distribution of Windsor Group salt, Atlantic Provinces and Gulf of St. Lawrence.

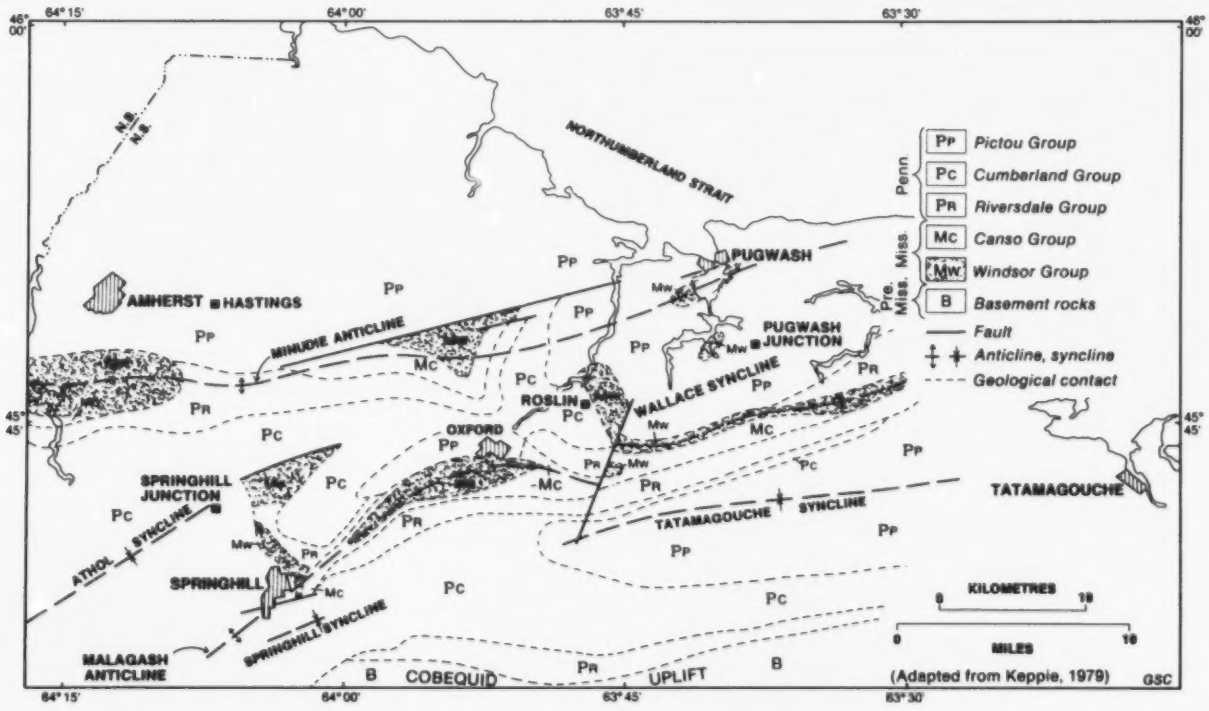

Figure 2. Geological map of the Cumberland subbasin, Nova Scotia.

WINDSOR GROUP SALT IN THE CUMBERLAND SUBBASIN OF NOVA SCOTIA

Abstract

The Paleozoic fold belt of Atlantic Canada forms the northeastern part of the Appalachian Mountains. Within this fold belt, the Windsor Group includes the only marine rocks of Late Paleozoic age in southeastern Canada. The Windsor Group evaporites, which are preserved on land in outliers or as part of the northeastern trending basin beneath the Gulf of St. Lawrence, form part of a much larger depositional area, the Magdalen Basin. Based on present structural trends, the Magdalen Basin has been divided into a number of subbasins. The Cumberland subbasin is one of these.

The Cumberland subbasin contains thick deposits of Upper Paleozoic rocks. Adjustments within the basement and uplift of the Cobequid basement block to the south, have folded the Carboniferous rocks in the subbasin into the east-northeast trending, salt-cored Malagash and Minudie anticlines and a few local structures. Massive salt accumulations occur as flow structures that are generally overturned to the north. The salt migration is considered to be the result of halokinesis and halotectonism associated with the Maritime Disturbance.

Résumé

La zone orogénique paléozoique de l'Atlantique canadian forme l'extrémité nord-est des Appalaches. A l'intérieur de cette zone, le groupe de Windsor contient les seules roches d'origine marine du Paléozoique récent dans le sud-est du Canada. Les évaporites du groupe de Windsor, qui se présentent sur terre, sous forme de buttes-témoins, ou dans le bassin à orientation nord-est qui se trouve sous le golfe Saint-Laurent, font partie d'une zone de sédimentation beaucoup plus vaste, le bassin Magdalen. D'après les tendances structurales actuelles, le bassin Magdalen a été divisé en un certain nombre de subbassins, dont le bassin Cumberland.

Le subbassin Cumberland contient d'épaisses accumulations de roches du Paléozoique supérieur. Des mouvements au sein du socle rocheux et le soulèvement du bloc rocheux de Cobequid au sud ont plié les roches carbonifères du bassin secondaire dans les anticlinaux de Malagash et de Minudie à orientation est-nord-est et à noyau de sel et dans quelques structures locales. Des accumulations massives de sel se présentent sous forme de structures fluidales généralement déversées dans la partie nord de la région. La migration du sel serait vraisemblablement le résultat d'une tectonique salifère associée au diastrophisme des Maritimes.

INTRODUCTION

Carboniferous rocks in the Cumberland subbasin have been folded and faulted both by tectonism and by halokinesis. The thickness of the Windsor Group salt, which is of Middle and Late Viséan, age and the depth of burial appear to be the factors that determined the shape of the preserved salt body. In areas where the Carboniferous section is considered to be at least 6100 m thick, the Windsor Group evaporites form the core of the structures. These evaporites, which may have migrated from burial depths of 3000 to 4500 m, are now less than 30 m below the surface in some areas.

The Carboniferous rocks in the Cumberland subbasin are generally poorly exposed because they have a fairly low resistance to erosion. The stratigraphic control was obtained from outcrop and from a few, widely spaced, exploratory boreholes, drilled for oil and gas, salt, potash, copper and uranium.

The subsurface geological data from this area are augmented by gravity and aeromagnetic maps. Cross-sections have been prepared using seismic and borehole data in order to show the general shapes of the Windsor Group evaporite bodies.

Acknowledgments

The author is particularly grateful for information provided by P.S. Giles and R.C. Boehner of the Nova Scotia Department of Mines and Energy; D.E.T. Bidgood and K. Howells of the Nova Scotia Research Foundation Corp.; G. Karg, Canadian Oil and Gas Lands Administration, Department of Energy, Mines and Resources; and the following companies: Anschutz (Canada) Exploration Ltd., Bowman Developments Ltd., Lacana Mining Corporation, and Scurry-Rainbow Oil Ltd. Special thanks are also extended to Geological Survey of Canada colleague B.V. Sanford and D. Umpleby (formerly with G.S.C.) for assistance and advice. The author also wishes to thank J.S. Bell, P.S. Giles and G.L. Williams, critical readers; M.P. Latremouille and J. Watt technical editors; H. Wiele, photography.

REGIONAL GEOLOGY

Windsor Group salt deposits are preserved in outliers in Nova Scotia and New Brunswick and in the main basinal area centred in the Gulf of St. Lawrence, which extends from Nova Scotia to western Newfoundland. These accumulations are considered to be erosional remnants of a much larger depositional area, the Magdalen Basin (Geological Survey of Canada, Map 1400A) of which the Cumberland subbasin (Fig. 1) is a marginal embayment on the southwest flank. The geological map of the area (Fig. 2), indicates that the Cumberland subbasin is terminated to the south by a basement complex, the Cobequid Uplift. Upper Paleozoic rocks outcrop in the area within a series of east-northeast trending folds.

The Horton Group, which is Eifelian to Early Viséan in age, underlies the Windsor Group and unconformably overlies the basement. The Horton Group is not exposed but has been identified in the subsurface. The Anschutz Wallace Station No. 1 well (Fig. 5) drilled for hydrocarbons in 1973, 29 km

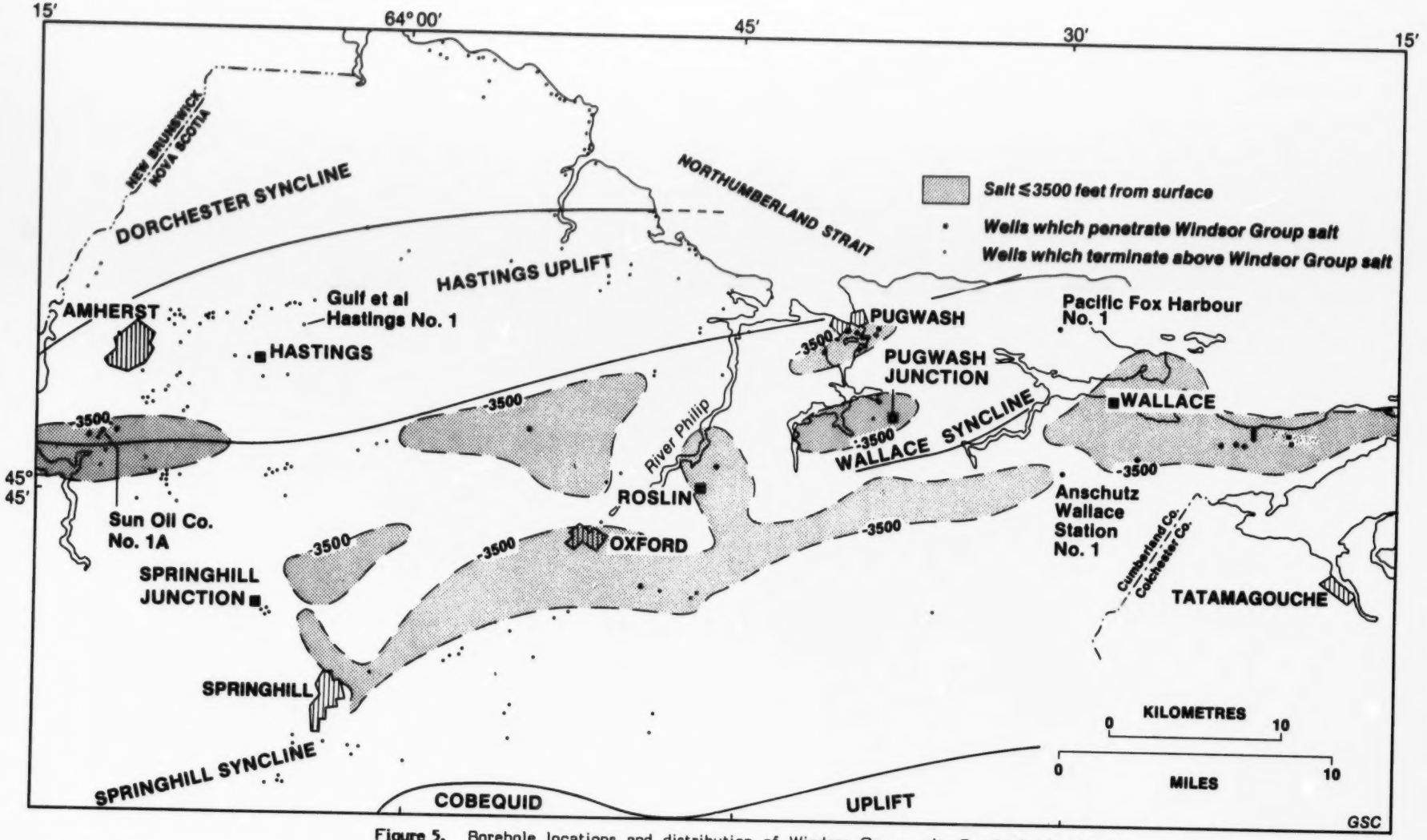

Figure 5. Borehole locations and distribution of Windsor Group salt, Cumberland subbasin, Nova Scotia.

east of Oxford penetrated 100 m of shale and siltstone and 92 m of nonmarine salt, which are assigned to the upper part of the Horton Group. This well bottomed in the Horton Group. Regionally, the nonmarine peidmont to fluviolacustrine Horton Group sequence attains thicknesses ranging up to 3350 m, (Gussow, 1953; Kelley, 1967). The salt in Wallace Station No. 1 is interpreted as part of a playa lake facies and this interval has been correlated with Horton Group salt present in southern New Brunswick and western Prince Edward Island (Howie, 1985a).

The Windsor Group overlies the Horton Group and contains the only record of marine sedimentation in the Upper Paleozoic section. This rock group, containing thick deposits of salt and anhydrite, is exposed at the surface along the Malagash and Minudie anticlines and in other small structures in the Springhill Junction, Roslin and Pugwash Junction areas. In the Anschutz Wallace Station No. 1 drill hole, 3567 m of Windsor Group sediments were penetrated. This does not represent the true thickness of the group because the section penetrated was highly contorted. It contained 274 m of shale and siltstone with some chert, carbonate, and anhydrite, overlain by 1463 m of salt. This salt body was in turn overlain by 1829 m of siltstone, shale, limestone, anhydrite or gypsum, which is in fault contact with the Canso Group.

The Canso Group (Namurian A), is a transition zone between the marine deposits of the Windsor Group and the continental sequences of the Riversdale Group, which are of Late Namurian to Early Westphalian A age. Bell (1958) estimated the average thickness of the Canso group in the Cumberland subbasin at about 850 m. The Canso Group is recognized in theAnschutz Wallace Station No. 1 borehole, where the uppermost 274 m of highly fractured siltstone is included in the group. In the Pacific Fox Harbour No. 1 borehole (Fig. 5) completed in 1974, and located about 9 km north of the Wallace Station No. 1 borehole, 915 m of Canso Group rocks have been recognized. This well encountered 457 m of shale and siltstore, overlain by 152 m of quartzose to arkosic conglomerate, which in turn is overlain by 305 m of shale and siltstone. As the Riversdale Group is not present in this well, the Pictou Group (Westphalian B to Wolfcampian), unconformably overlies the Canso Group.

Although the Riversdale Group was not present in the Wallace Station No. 1 well it was recognized in the Gulf Hastings No. 1 borehole (Fig. 5), completed in 1975 about 11 km east of Amherst. This borehole penetrated 1646 m of sediments conformably overlying the Canso Group, which are assigned to the Riversdale Group. The lower part of this sequence consists of 69 m of sandstone and sandy siltstone, overlain by 27 m of quartzose conglomerate. Although the company drill log of this borehole records a minor salt water flow in the conglomerate, actual measurements were not recorded. The conglomerate was overlain by 1550 m of fairly compact, medium- to fine-grained sandstone and some sandy siltstone. The Cumberland Group is not present in this well. The Riversdale Group is overlain by the Pictou Group.

The Cumberland Group overlies the Riversdale Group and consists of a locally thick deposit of continental sediments that have not been identified outside the Cumberland subbasin. Bell (1958) and Copeland (1959) indicated the Cumberland Group may be up to 3350 m thick. It is a local facies that was deposited relatively quickly in a rapidly subsiding area. This rock group is composed of conglomerate, sandstone, shale, and local economic deposits of coal in the springhill area as well as west of the study area. Howie and Barss (1975a, 1975b) suggested that the Cumberland Group may in part be the lateral equivalent of some of the upper beds of the Riversdale Group and some of the lower beds of the Pictou Group.

The Pictou Group, with an estimated maximum thickness of 2256 m (Bell, 1958), is the youngest Upper Paleozoic rock unit in the Maritimes. In the Cumberland subbasin, the Pictou Group is largely composed of conglomerate, sandstone, siltstone, shale, with rare, thin coal seams, and carbonaceous shale. Although the Pictou Group is only 1067 m thick in the Gulf et al. Hastings No. 1 borehole (Fig. 5), its total thickness in the Cumberland subbasin is estimated to be about 1829 m. The section encountered in the borehole unconformably overlies the Riversdale Group and is composed of sandstone, sandy siltstone, and siltstone.

STRUCTURAL GEOLOGY

The Upper Paleozoic rocks in the northeast-trending Cumberland subbasin, which may range in thickness up to about 6100 m (Bell, 1958), are underlain by a highly fractured basement. As illustrated on Figure 2, Windsor Group rocks outcrop along the crest of the Minudie and Malagash anticlines and near Springhill Junction, and also around Roslin and Pugwash Junction area in the synclinal zone between the two anticlines. These folds are interpreted to owe their origin to halokinesis (salt tectonics), combined with halotectonism (compressive tectonic forces), associated with post-Windsor Group tectonism. This tectonism is generally referred to as the Maritime Disturbance and it reactivated many of the faults which were originally formed during the Acadian (Devonian) Orogeny (Poole, 1967).

In the Cumberland subbasin, the thickness of the salt as well as its depth of burial may be the main factors which determined the shape of the salt bodies preserved as domes, diapirs or anticlines. Such casual relationships have been documented by Trusheim (1960) for salt deposits in northern Germany. In the Zechstein basin of northern Germany, Trusheim indicated 305 m of salt with 915 m of cover rock was sufficient to induce salt flowage. This is less than the salt thickness of about 610 m that Nettleton (1934) suggested was necessary for salt migration, exclusive of tectonism. It also conflicts with the findings of Parker an McDwoell (1951), who on the basis of experimental data, concluded that a salt thickness of 1524 m, was a more realistic figure. Regardless of the thickness or depth of a burial required for movement, once the plasticity of the salt has overcome the elasticity, the density contrast between the salt and the surrounding rock appears to be sufficient to maintan growth. In regions where the salt has a thick sediment cover, such as the U.S. Gulf Coast, the vertical element of crustal deformation overshadows all other directions of strain (Murray, 1966). As a result, salt will rise until the gravitational equilibrium of the salt with the surrounding rock is reached. In areas like the Cumberland subbasin, which were tectonically unstable during the deposition of the Canso, Riversdale and Pictou groups, halotectonism may have been partly or entirely responsible for salt migration, regardless of the thickness of the deposit or depth of burial. It is therefore reasonable to infer that both halokinesis and halotectonism were responsible for salt migration and the geometry of diapiric bodies.

Five cross-sections have been prepared to show the effects of tectonism and salt movement on the distribution and thickness of the Carboniferous rocks in the Cumberland subbasin (Fig. 3 and 4). The index map for these sections is shown in Figure 3. The sections are based on data from the Sun Oil Co. No. 1A, Gulf Hastings No. 1, Pacific Fox Harbour No. 1 and the Anschutz Wallace Station No. 1 deep wells, a few shallow boreholes, limited seismic and gravity data, the salt mine at Pugwash and the regional geological map.

Section A to A', crosses the Amherst area, and was constructed to include the Sun Oil Co. No. 1A well. At the north end of this cross-section, in the Dorchester Syncline

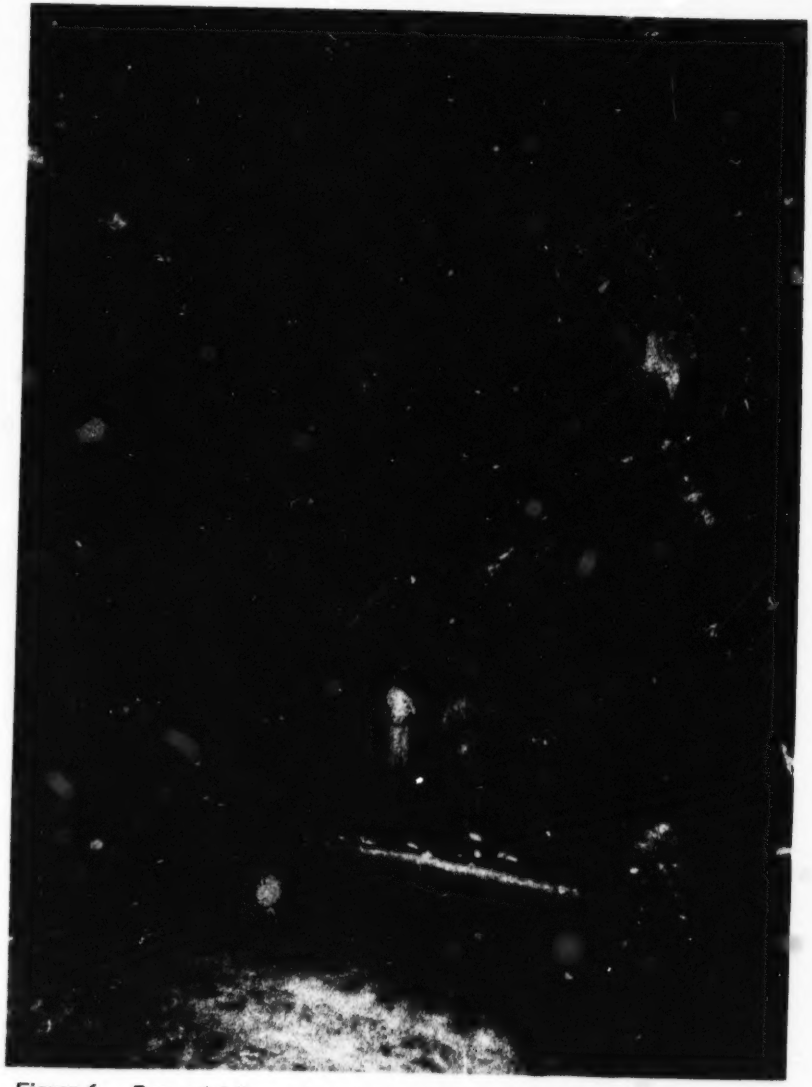

Figure 6. Pugwash Mine, anhydrite overlain by salt. GSC 204391-A

Figure 7. Pugwash Mine, close up anhydrite-salt contact. GSC 204391-B

Figure 8. Pugwash Mine, near vertically bedded salt. GSC 204391-C

Figure 9. Pugwash Mine, salt syncline. GSC 204391-D

Figure 10. Pugwash Mine, close up of syncline. GSC 204391-E

Figure 11. Pugwash Mine, "M" shaped fold structure in salt. GSC 204391-F

Figure 12. Pugwash Mine, close up of part of "M" structure. GSC 204391-G

(Gussow, 1953), there is a stratigraphic sequence of gently dipping Horton to Pictou Group rocks overlying the pre-Mississippian basement complex. Section line D-D' follows the Minudie anticline (Evans, 1970), which is an evaporite-cored structure that has been traced for over 80 km. On this cross-section it is also coincident with a basement feature designated the Hastings Uplift (Fig. 3, section C-C' Howie, 1985a). To the south in the Athol Syncline (Copeland, 1959), Horton Group to Cumberland Group rocks are present (Fig. 3, section A-A').

Tectonically, it appears that much of the salt originally deposited in the Athol Syncline, has migrated up dip over the Hastings Uplift basement ridge to form the diapiric Minudie anticline. Growth of this flow structure also overturned some of the younger Upper Paleozoic sediments of the Canso and Riversdale groups in the Dorchester syncline, as documented by the Sun Oil Co. No. 1A borehole.

Section B-B' extends from the Dorchester syncline to the Cobequid Uplift. In the Dorchester syncline, the gently dipping Horton to Riversdale and Pictou groups are present. The Cumberland Group was not included in the stratigraphic section because it was not present in the Gulf et al. Hastings No. 1 borehole. The Minudie Anticline, Athol Syncline and Malagash Anticline (Evans, 1970), are structurally very complex areas that contain thick accumulations of domal to diapiric salt. In both the Minudie and Malagash structures, the salt appears to have migrated up dip from south to north. In the Springhill syncline, the Horton to Cumberland groups are present. The proposed thinning of the Riversdale Group in this area is attributed to local uplift and erosion due to salt migration during the Maritime Disturbance, prior to the deposition of the Cumberland Group.

Section C-C' extends from the northern coast of Nova Scotia to the Cobequid Uplift. Areas underlain by the Hastings Uplift and the Minudie anticline, contain rocks of the Horton to Riversdale groups, which are unconformably overlain by rocks of the Pictou Group. As indicated on the cross-section, the Pacific Fox Harbour No. 1 well encountered only minor amounts of Windsor Group salt. The term Wallace Syncline is herein proposed for the downwarped zone between the Minudie and Malagash anticlines in the eastern part of the map area (Fig. 2). It contains Horton to Riversdale and Pictou Group rocks. The Riversdale Group gradually thickens from north to south below the unconformity with the Pictou Group. The Windsor Group salt section also gradually thickens from north to south on the flanks of the Malagash anticline.

In the Malagash anticline area both the Horton and Windsor groups contain salt. As indicated in the Anschutz Wallace Station No. 1 well, the Horton Group salt appears to be an undisturbed, bedded deposit, whereas the Windsor Group salt is deformed into a domal to partly diapiric body.

The Tatamagouche syncline (Donohoe and Wallace, 1982) contains a thick section from the Horton to the Pictou Group. The Cumberland Group is shown as a wedge of sediments thinning from south to north.

Cross-sections D-D' and E-E' (Fig. 4) trend west to east along the crest of the Minudie and Malagash anticlines respectively. A highly faulted basement with thick deposits of Windsor Group salt are the dominant features of both sections. East of the Amherst area, the Windsor Group is overlain by the Canso and Riversdale groups. In the River Philip area (Fig. 5), a relatively thin section of Windsor Group evaporites is overlain by a thick sequence of Canso to Pictou Group rocks. This area can be compared with the Tatamagouche syncline (Fig. 3, section C-C'), which also contains a thick section of post-Windsor Group sediments.

In the Pugwash area, Windsor Group rocks exposed at the surface form part of a large salt dome or diapir. This is the site of the Canadian Rock Salt Co. Ltd. mine which was brought into production in 1959. The mine was located on a peninsula in Pugwash Harbour. As part of the mine is beneath the harbour, the siltstone-anhydrite-gypsum caprock is considered to have formed a good seal (Howie, 1985b). Detailed mapping of the underground workings by Evans (1967) confirmed that the salt deposit is severely deformed. As the preliminary deformation had a substantial lateral as well as a vertical component, there is no consistent vertical orientation of axial planes or axes. Every transition from horizontal to vertical axes and planes has been observed in the mine. Folds range in size from a few centimetres to 100 m and may be symmetrical, overturned, or recumbent. The salt is removed in a non-systematic pattern rather than in a grid or room an pillar method, because the salt/anhydrite ratio is difficult to predict over much of the deposit prior to horizontal drilling. Figures 6 and 7 show steeply dipping salt (light tone) overlying fairly massive anhydrite (dark tone). The colour banding in the salt is due to slight discoloration rather than major impurities.

Vertical banding of the salt is shown in Figure 8. A tightly folded salt syncline is shown in Figures 9 and 10. The marble-like appearance in this fairly pure salt is due to impurities. One of the many complicated recumbent folds is illustrated in Figure 11. A close-up of the lower left limb of this structure is shown in Figure 12.

East of Pugwash, the Windsor Group salt appears to pinch out and then gradually thickens at the eastern end of

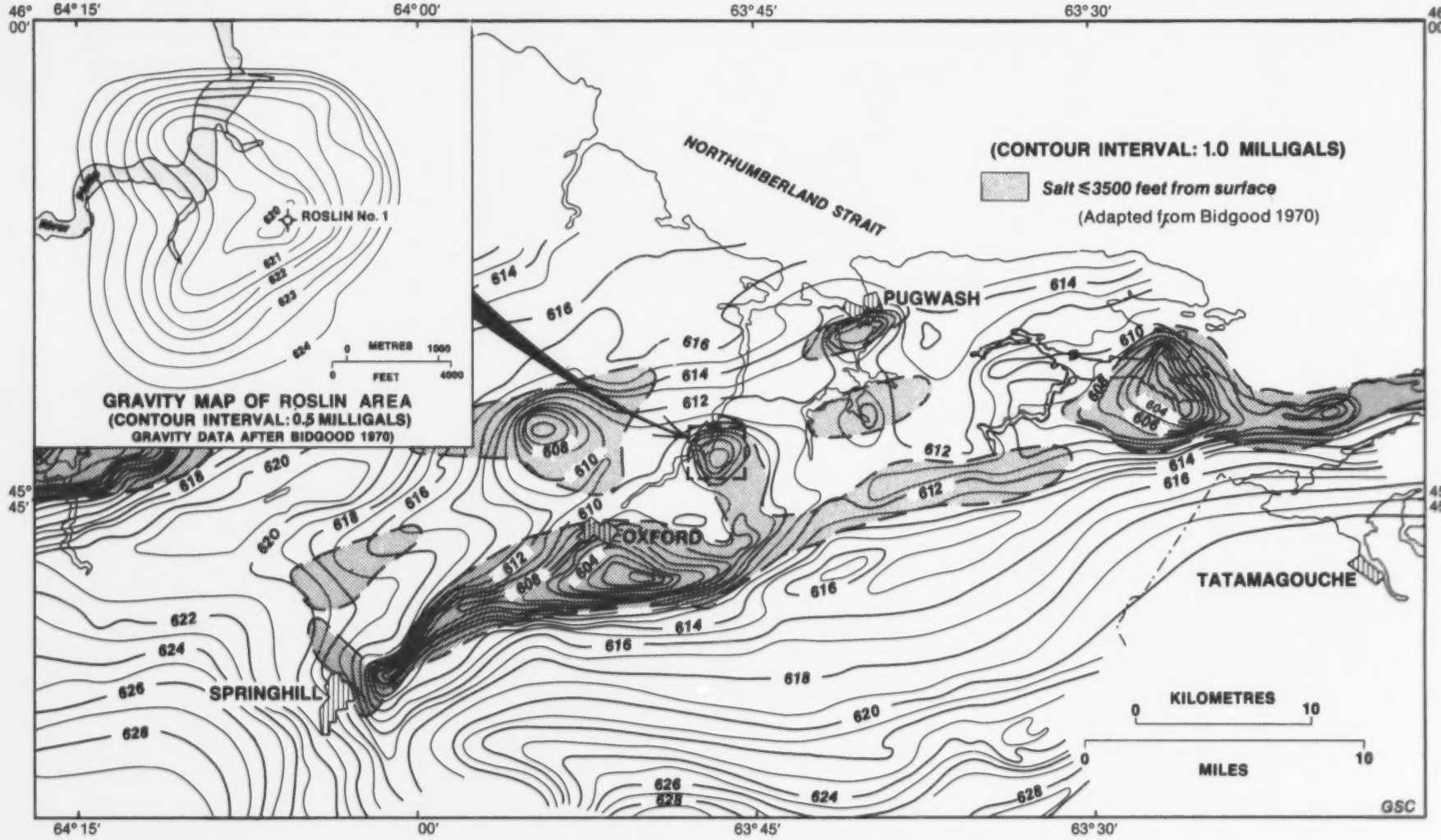

Figure 13. Gravity map, Cumberland subbasin, Nova Scotia.

section D-D'. This reduction in thickness was also observed in the Pacific Fox Harbour No. 1 well, in the same vicinity (Fig. 3, section C-C').

Section E-E', (Fig. 4) along the crest of the Malagash anticline, extends from the Springhill area in the west, to the north coast of Nova Scotia. A highly faulted basement, thick deposits of Windsor Group salt, and the west-to-east lateral transition from anhydrite to siltstone in the beds immediately above and below the salt are the major features of this section. Windsor Group rocks are exposed along the crest of the Malagash anticline except in the Springhill and Oxford areas. In the highly faulted area around Springhill at the western end of the section, the Windsor Group is overlain by rocks of the Canso, Riversdale and Cumberland groups. In the horst area east of Springhill, the Windsor Group is exposed at the surface. From the horst structure, to a fault east of Oxford the Windsor Group outcrops except for a short distance at either end of the section which is overlain by the Canso Group.

The faults east of Oxford offset the crest of the Malagash anticline by about 3 km (Fig. 2). East of this fault, the crest of the anticline is displaced northwards relative to its axis west of the fault. In order to restore the crest of the anticline to the line of section, the apparent normal fault on the cross-section may actually represent a thrust or strike slip fault.

Near the eastern end of section E-E', the Malagash Mine is shown as a local horst structure. Wells drilled in this area encountered salt within 28 m of the surface.

A map has been prepared to show the borehole locations and the distribution of salt to a depth of about 1065 m (Fig. 5). The distribution of salt on this map, corresponds very closely to the distribution of the Windsor Group shown on Figure 2 because the Windsor Group contains salt-cored structures.

A regional gravity map has also been prepared for the same area (Fig. 13). The shaded area on the map is an overprint of Figure 5 showing the distribution of salt encountered at depths equal to or less than 1065 m. The gravity lows correspond fairly well to the near-surface salt structures. The insert on the upper left corner of the map is a detailed gravity map of the Roslin area. The Roslin No. 1 borehole, drilled near the centre of this gravity low, penetrated 115 m of siltstone-claystone-gypsum caprock and 192 m of salt with siltstone, before it was completed at 306 m.

The regional aeromagnetic map of the same area has smooth, widely spaced contours, suggesting a thick sedimentary section (Fig. 14). The 2500 gamma closures, shown as patterned areas on the map, are considered to represent anomalies associated with minor structural highs within the basement. The apparent change of pattern inside the 2500 gamma closures south of Oxford, is strictly an artifact due to the partial overlap of two adjacent surveys. The insert in the upper left corner of the map gives details of a magnetic anomaly over a basement feature in the Roslin area. The shaded area on the map is an overprint showing the distribution of salt that is buried to depths equal to or less than 1065 m. The magnetic anomalies correspond fairly well with the distribution of the salt-cored structures.

TECTONIC EVOLUTION

A regional tectonic map of the Cumberland and Minas subbasins has been prepared to show the effects of the Maritime Disturbance on the Cobequid Uplift and adjacent areas (Fig. 15). In the north, the Hastings Uplift was unaffected by the Cobequid Uplift. The Hastings Uplift is a subsurface basement high. South of the Hastings Uplift, the Cumberland subbasin is a highly disturbed area that contains the Minudie and Malagash anticlines. The Cobequid Uplift is shown as a basement horst that separates the Cumberland subbasin from the Minas subbasin. Like their counterparts in the Cumberland subbasin, the Upper Paleozoic rocks in the Minas subbasin, adjacent to the south side of the Cobequid Uplift, are also highly disturbed. However, farther south in the Minas subbasin, the Upper Paleozoic rocks in the Shubenacadie area are interpreted as being unaffected by the Cobequid Uplift because they represent a cover sequence on the Nova Scotia Platform, which is considered to be basement. These relationships are illustrated on cross-section A-A' which crosses both the Cumberland and Minas subbasins.

When the Cobequid basement block began its upward movement, the Upper Paleozoic sediments in the Cumberland subbasin were compressed between the Hastings Uplift on the north and the Cobequid Uplift on the south. As a result, the sediments were folded and slightly overturned to the north, as illustrated by the asymmetric configuration of the Windsor Group salt. In the Amherst area the Windsor Group evaporites, shown as part of the Minudie anticline, overlie the western end of the Hastings Uplift (Fig. 3, section A-A'). When the area was tectonically disturbed, it is believed that the salt migrated north, out of the Athol syncline, to form a salt dome on top of the basement ridge. According to this model, as the salt continued to flow, the dome became a recumbent fold overturned to the north. Continued salt movement into this structure converted the recumbent fold into an overthrust nappe. This Windsor Group evaporite sequence is now preserved as an asymmetric salt diapir that was produced from salt which probably originated from a depth of up to 4575 m. Section B-B' (Fig. 3) interprets the Minudie anticline as a salt-cored structure also overthrust to the north. The Malagash anticline and the Athol syncline also contain diapiric salt structures. In the Springhill syncline, the thinning of the Riversdale Group is attributed to local uplift and erosion due to salt migration, prior to the deposition of the Cumberland Group. The thick section of Windsor Group evaporites in the Malagash anticline shown on section C-C' may be the result of northward migration of salt out of the Tatamagouche syncline.

ECONOMIC GEOLOGY

Salt

Amherst

South of Amherst, in the vicinity of the Sunoco No. 1A borehole, Domtar Chemicals Ltd. has been bringing salt from a number of wells drilled into the salt. In this type of operation, freshwater is pumped down and the resultant brine is pumped back to the surface. In recent years, underground water has broken through the caprock and flooded the area once occupied by salt. As a result, the brine can now be removed without adding freshwater. Information is not available to determine if some of the brine is also flowing out of the formation as groundwater. The annual production varies from 80 000 to 95 000 tons of salt (Stonehouse, 1978).

Malagash

In 1919, about 3 km northwest of the town of Malagash (Fig. 15), the Canadian Rock Salt Co. Ltd. opened a mine that produced salt for forty years. Until 1955 this was the only salt mine in Canada. It was extracted by the open slope system from three seams which had an average dip of 45 degrees (Nova Scotia Department of Mines, 1950). The average width of mining was approximately 2 m with a maximum of 4 m. The mine was closed in 1959.

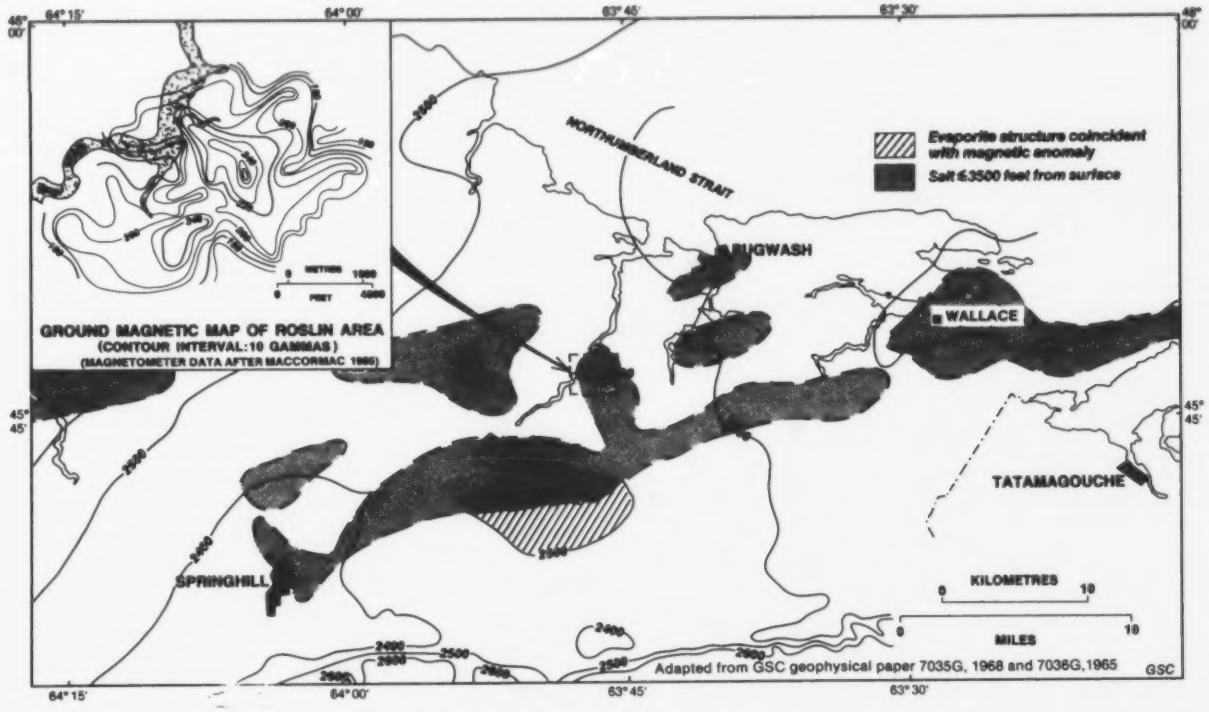

Figure 14. Aeromagnetic map, Cumberland subbasin, Nova Scotia.

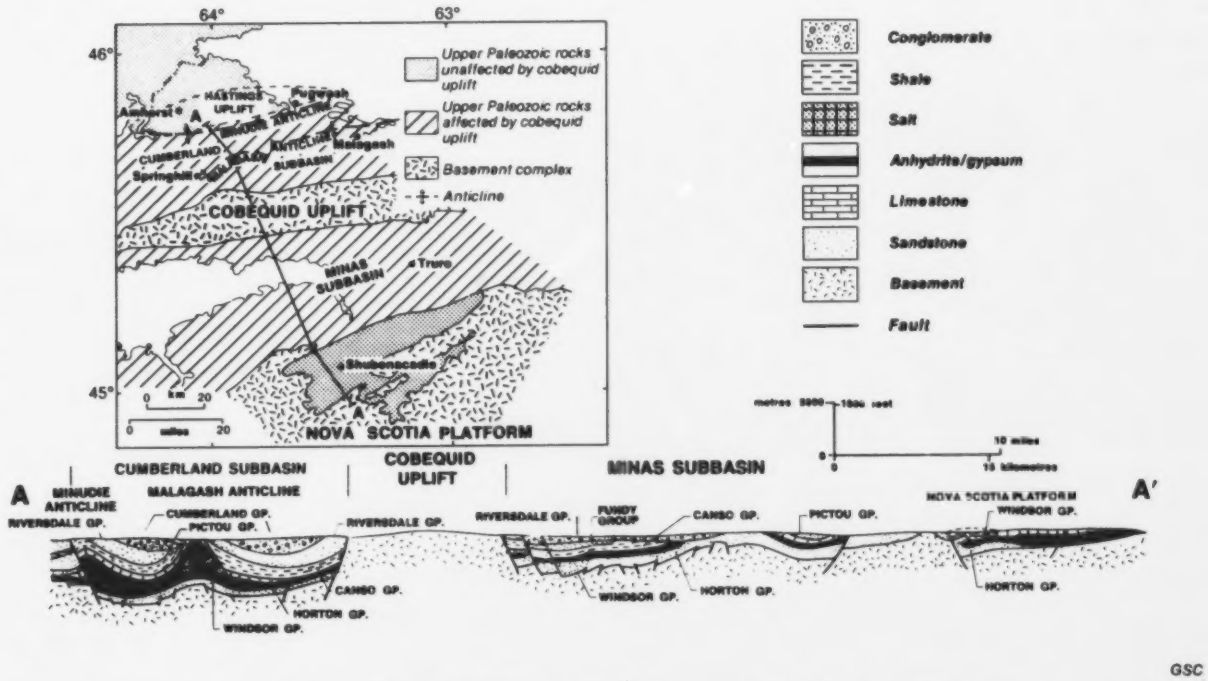

Figure 15. Effects of Maritime Disturbance on the Cobequid Uplift and adjacent areas.

Pugwash

In 1959, the Canadian Rock Salt Co. Ltd. opened a mine at Pugwash as a replacement for the uneconomic Malagash Mine. For the first 15 years salt was extracted from the 192 m level. Salt is now being extracted from the 253 m level. The mine produces 900 000 tons of salt and 600 000 tons of anhydrite annually (Stonehouse, 1978).

Potash

In the Cumberland subbasin, potash has been reported from the mine at Malagash, in two boreholes near Wallace, and in the salt mine at Pugwash (Baar, 1966; Bancroft, 1957; Cameron, 1967; Evans, 1967, 1970; Nova Scotia Department of Mines, 1950; Shea, 1070). The above data suggest this area has a potential for potash.

SUMMARY

Reactivation of the faults beneath the Cumberland subbasin and the uplift of the Cobequid basement block to the south during the deposition of the Canso and Riverdale groups, are considered to have initiated diapiric movement of the Windsor Group evaporites. This tectonism (Maritime Disturbance), involved the north-south compression of the Upper Paleozoic rocks in the Cumberland subbasin, which formed the Malagash and Minudie anticlines, together with three smaller uplifts, located in the syncline between the anticlines (Fig. 2). Most of the unconformities, faults, and recumbent folds that evolved during this period of readjustment were later blanketed by rocks of the Cumberland and Pictou groups.

Although the rocks overlying the salt have been highly disturbed, the anhydrite, dense carbonate, and siltstone in the upper beds of the Windsor Group and the high silt content of the Canso, Riversdale, Cumberland, and Pictou groups appear to have sealed the salt from dissolution.

BIBLIOGRAPHY

Baar, C.A.
1966: Bromine investigations on eastern Canada salt deposits; in Second Symposium on Salt, edited by J.L. Rau; the Northern Ohio Geological Society Inc., Cleveland, Ohio, v. 1, p. 276-292.

Bancroft, M.F.
1957: Salt deposits at Malagash and Pugwash, Nova Scotia; in Geology of Canadian Industrial Mineral Deposits, Canadian Institute of Mining and Metallurgy (Sixth Commonwealth Mining Metallurgical Congress), p. 215-218.

Bell, W.A.
1958: Possibilities for occurrences of petroleum reserves in Nova Scotia; Nova Scotia Department of Mines, 177 p.

Bidgood, D.E.T.
1970: The distribution and nature of some Nova Scotia evaporites – a geophysical evaluation; in Third Symposium on Salt, edited by J.L. Rau and L.F. Dellwig; the Northern Ohio Geological Society Inc., Cleveland, Ohio, v. 1, p. 298-305.

Cameron, R.A.
1967: Potash Project; for Atlantic Development Board and Nova Scotia Department of Mines; Geological Report, Summer 1966, 8 p.

Copeland, J.J.
1959: Coalfields west half Cumberland County, Nova Scotia; Geological Survey of Canada, Memoir 298, 89 p.

Donahoe, H.V. Jr. and Wallace, P.I.
1982: Geological Map of the Cobequid Highlands Nova Scotia, Maps 82-6, 7, 8 and 9. Nova Scotia Department of Mines and Energy.

Evans, R.
1967: Structure of the Mississippian evaporite desposits at Pugwash Cumberland County, Nova Scotia; Economic Geology, v. 62, No. 2, p. 262-273.

1970: Genesis of sylvite and carnallite bearing rocks from Wallace, Nova Scotia; in Third Symposium on Salt, edited by J.L. Rau and L.F. Dellwig; Northern Ohio Geological Society Inc., Cleveland, Ohio, v. 1, p. 239-245.

Geological Survey of Canada
1965: Aeromagnetic series, Map 7036G Amherst, Nova Scotia, scale 1:253 440.

1968: Aeromagnetic series, Map 7035G, Truro, Nova Scotia, scale 1:253 440.

1977: Basement structure eastern Canada and adjacent areas, map 1400 A, scale 1:2 000 000.

Gussow, W.C.
1953: Carboniferous stratigraphy and structural geology of New Brunswick, Canada; American Association of Petroleum Geologists Bulletin, v. 37, No. 7 p. 1713-1816.

Howie, R.D.
1970: Oil and gas exploration – Atlantic coast of Canada; American Association of Petroleum Geologists Bulletin, v. 54, No. 11, p. 1992-1994.

1985a: Carboniferous evaporites in Atlantic Canada; Compte Rendu, Proceedings of 9th Carboniferous Congress, Urbana-Champaign, Illinois, U.S.A., 1979. v. 3, p. 137-142.

1985b: Windsor Group salt in the Minas subbasin of Nova Scotia, Geological Survey of Canada, Paper 85-10.

Howie, R.D. and Barss, M.S.
1975a: Upper Paleozoic rocks of the Atlantic Provinces, Gulf of St. Lawrence and adjacent continental shelf; Geological Survey of Canada, Paper 74-30, v. 2, p. 35-50.

1975b: Paleogeography and sedimentation in the Upper Paleozoic, eastern Canada; in Canada's Continental Margins and Offshore Petroleum Exploration, C.J. Yorath, E.R. Parker and D.J. Glass; Canadian Society of Petroleum Geologists, Memoir 4, p. 45-57.

Kelley, D.G.
1967: Baddeck and Whycocomagh map-areas with emphasis on Mississippian stratigraphy on central Cape Breton Island, Nova Scotia (11K/2 and 11F/14); Geological Survey of Canada, Memoir 251, p. 55-59.

MacCormack, L.
1965: Magnetometer Survey, Roslin area, Cumberland Co., Nova Scotia; Nova Scotia Department of Mines and Energy; Map; scale 1:15 000.

Murray, G.E.
1966: Salt structures of Gulf of Mexico Basin – A review; American Association of Petroleum Geologists Bulletin, v. 50, No. 3, p. 431-478.

Nettleton, L.L.
1934: Fluid mechanics of salt domes; American Association of Petroleum Geologists Bulletin, v. 18, No. 9, p. 1175-1204.

Nova Scotia Department of Mines.
1950: Salt and potash in Nova Scotia; Open File Report, 14 p.

Parker, T.J. and McDowell A.N.
1951: Scale models as guide to interpretation of salt dome faulting; American Association of Petroleum Geologists Bulletin, v. 35, No. 9, p. 2076-2086.

Poole, W.H.
1967: Tectonic evolution of Appalachian region of Canada; in Collected papers in geology of the Atlantic region; Geological Association of Canada; Special paper No. 4, p. 9-51.

Shea, F.S.
1970: Salt basins in Nova Scotia; in Third Symposium on Salt, edited by J.L. Rau and L.F. Dellwig; the Northern Ohio Geological Society Inc., Cleveland, Ohio, v. 1, p. 306-316.

Stonehouse, D.H.
1978: Salt; Canadian Minerals Yearbook, 1977; Energy, Mines and Resources, p. 8.

Trusheim, F.
1960: Mechanics of salt migration in northern Germany; American Association of Petroleum Geologists Bulletin, v. 44, No. 9, p. 1519-1541.

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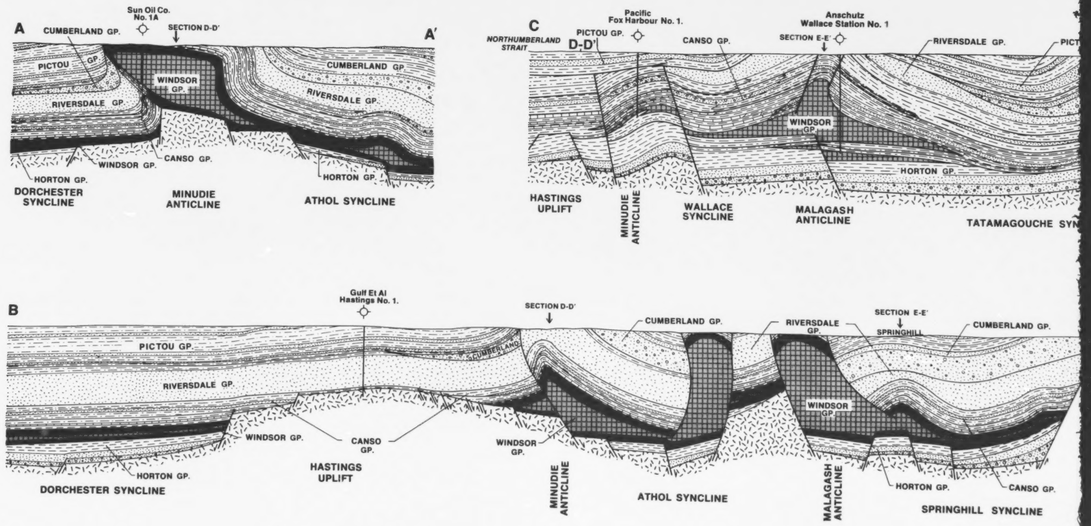

FIGURE 3 : CROSS SECTIONS A-A′, B-B′ AND C-C′, CUMBERLAND SUBBASIN, NOVA SCOTIA

NS A-A′, B-B′ AND C-C′, CUMBERLAND SUBBASIN, NOVA SCOTIA

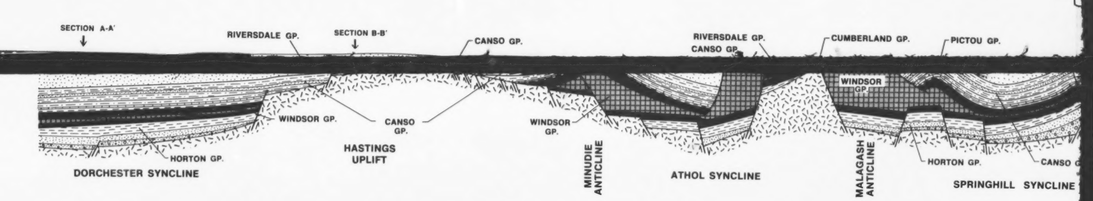

FIGURE 3 : CROSS SECTIONS A-A′, B-B′ AND C-C′, CUMBERLAND SUBBASIN, NOVA SCOTIA

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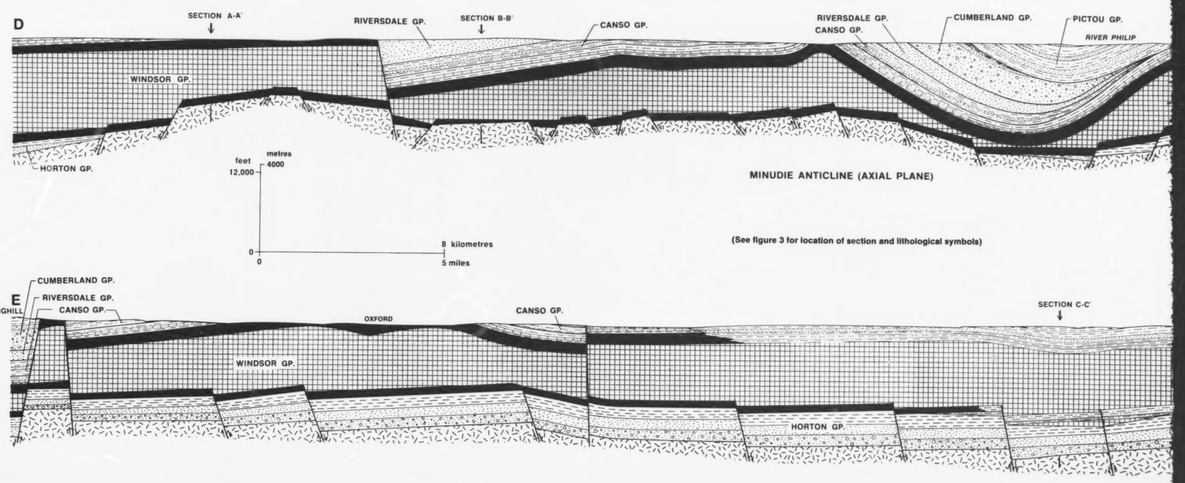

FIGURE 4 : CROSS-SECTIONS D-D′ AND E-E′, CUMBERLAND SUBBASIN, NOVA SCO

E 4 : CROSS-SECTIONS D-D′ AND E-E′, CUMBERLAND SUBBASIN, NOVA SCOTIA

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